CERTIFICATION OF TRANSLATION

I am fluent in both the German and English language and hereby certify that the attached is a true and correct translation of the application.

Dated: August 10, 2001

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5/PRTS

09/913340

Method and Device for Determining the Vehicle Reference Speed and for Detecting an Incorrect Vehicle Reference Speed of an All-Wheel-Drive Vehicle

The present invention relates to a method and a device for determining the vehicle reference speed and for detecting an incorrect vehicle reference speed of an all-wheel-drive vehicle according to the preambles of the independent claims. A corresponding determination method is disclosed in DE 197 32 554.

A problem that appears in all-wheel driven vehicles is that all wheels may suffer from traction slip so that in the driving action there is no standard for the vehicle reference speed which is usually determined from the wheel speed. In one-axle drive vehicles this problem cannot occur in the driving action because at least the non-driven axle may exhibit no traction slip. Thus, the wheels of this axle always permit being taken as a standard for the reference speed.

DE 197 32 554 A1 discloses a method and a device for determining the speed of an all-wheel-drive vehicle. In this application, individual wheel accelerations are related to the prevailing engine torque and compared one to the other in order to initially detect the condition that all wheels spin, as the case may be, and to then take a remedy. A disadvantage of this method is that, for different reasons, the detection thresholds must be chosen to be comparatively coarse to prevent incorrect detections so that the detection is not very exact. In addition, a comparatively high expenditure in data processing

is incurred due to the separate analysis of individual wheel accelerations.

An object of the present invention is to provide a method and a device for determining the vehicle reference speed which achieve correct results in a reliable fashion and with little effort.

When situations appear where the wheel speeds alone are no longer sufficient for a reliable determination of the vehicle reference speed, alternative strategies are used. Such conditions can last for a comparatively long time, for example, when a driver rides with spinning wheels at a low coefficient of friction, or when the vehicle is accelerated under specific conditions in a hill ascent or descent, especially when driving downhill. The vehicle reference speed which is determined as a substitute (for example, by extrapolation) becomes increasingly inaccurate in this case, and there is the necessity to find out whether the value, which is determined as a substitute (e.g. by extrapolation), is still sufficiently exact, and, in the negative, to produce a more exact signal in any other way.

Another object of the present invention is directed to providing a method and a device which permit detecting an incorrect vehicle reference speed and, as the case may be, determining it in a modified fashion. These objects are achieved with the features of the independent claims. Dependent claims deal with preferred embodiments of the present invention.

Apart from the determination of the vehicle reference speed from the signals of one or more wheel sensors, the vehicle acceleration, especially the vehicle longitudinal acceleration, is determined indirectly or directly from the wheel signals,

and, in a comparative analysis, is related to a drive torque and/or to a vehicle acceleration measured by means of a sensor. In particular, a plausibility assessment of the vehicle acceleration determined from the wheel speeds is executed. When this assessment appears unplausible in consideration of the measured vehicle acceleration or the drive torque, the vehicle reference speed determined from the wheel sensors is modified, for example, by extrapolating it on the basis of a vehicle acceleration. More particularly, a value of the vehicle reference speed which was considered to be correct as last can be extrapolated with a still plausible value of the vehicle acceleration.

A table may be provided which comprises acceleration values in dependence on a drive torque and, if appropriate, also in dependence on the gear step of the vehicle. Tabulated accelerations based on the drive torque and, if necessary, based on the gear step and/or the vehicle speed can be taken from this table, and this tabulated acceleration is compared with the acceleration determined from the wheel signals.

In a method of detecting an incorrect vehicle reference speed of an all-wheel-drive vehicle, one or more wheels can be decoupled from the drive, and the detection of the incorrect vehicle reference speed is effected with respect to the running behavior of the decoupled wheel(s).

Decoupling can be carried out e.g. axlewise by decoupling one axle from the drive by way of an appropriate center clutch. Decoupling can take place depending on the driving situation of the vehicle. Especially, the detection can be carried out based on the running behavior of the decoupled wheels directly after the decoupling action. The gradient (acceleration, maybe

negative) can be examined and especially compared with a threshold value (maybe also negative).

Preferably, the detection method is employed when a modified vehicle reference speed (as has been described hereinabove) was determined especially over a long period of time. It can then be checked inasfar as the modified vehicle reference speed still corresponds to the actual speed. When the modified vehicle reference speed is detected as incorrect, a modified method of determining the vehicle reference speed can be taken into consideration, for example, by determining the vehicle reference speed from the wheel sensor signals of the then decoupled wheels.

Individual embodiments of the present invention will be described hereinbelow by making reference to the accompanying drawings. In the drawings,

Figure 1 is a schematic block diagram of a vehicle in which the present invention can be implemented.

Figure 2 is a schematic block diagram showing a determination system.

Figure 3 is an exemplary table.

Figure 4 is a block diagram of a detection system.

Figure 5 is a schematic diagram of a method of determining the vehicle reference speed.

Figure 1 shows components of a vehicle in a schematic view. Reference numerals 10a-d designate the wheels of the vehicles, reference numerals 11a-d refer to wheel sensors associated with

the respective wheels and furnishing signals relating to the wheel speed, and other data. 12a designates the front axle, 12b designates the rear axle. 13 refers to the drive, especially the engine. 14a refers to the mechanical transmission, 14b the center transmission. 14c and 14d are differentials in the axles. 15a designates a rotational speed sensor, 15b a torque sensor, both on the output end of the engine. Reference numeral 16 designates an (optionally provided) acceleration sensor. 17 refers to an evaluation device which may comprise individual components or devices. It can provide the brake control and the engine control. It generates output signals 18 for control members (not shown) such as wheel brakes, throttle valve, etc. The device 17 receives the signals of the mentioned sensors and determines from them, apart from manifold quantities and signals, the vehicle reference speed which, in turn, is required in many components of the device 17.

Figure 2 shows a device for determining the vehicle reference speed in a schematic block diagram. Reference numeral 21 designates a first determination system for determining the vehicle reference speed from one or more wheel speeds. System 21 can operate in a known fashion. Line 21a symbolizes the vehicle reference speed v_{ref}. Reference numeral 22 is assigned to a second determination system which determines the vehicle acceleration A_{ref}, herein from the vehicle reference speed v_{ref}. 22a symbolizes A_{ref}.

Reference numeral 23 represents a third determination system for determining a drive torque. It will receive signals from the sensor 15b, e.g. at the engine output end, and condition and relay them as the necessity may be. 24 and 25 together form a comparison system for a comparative analysis of the determined vehicle acceleration A_{ref} and the drive torque M_{mot} which is represented by line 23a. Comparable quantities may be

produced in that acceleration values are stored, for example, in a memory 24, and based on the engine torque M_{mot} are read out via line 24a as tabulated acceleration A_{tab} and compared with the vehicle reference acceleration A_{ref} 22a in a comparator 25. 24b represents an addressing system for the memory 24. The addressing system 24b can access the memory based on the engine torque on line 23a. Further influencing variables can be the gear steps (represented by line 23b) and the vehicle reference speed V_{ref} (represented by the extension of line 21a).

The tabulated acceleration A_{tab} and the vehicle reference acceleration A_{ref} are compared in comparator 25. When the result of the comparison is unplausible values (especially $A_{ref} > A_{tab}$), this is taken as an indication of an incorrect vehicle reference speed V_{ref}, and a modification system 26 is activated accordingly to issue a modified vehicle reference speed V_{mod} on line 26a for further reference. When no modification takes place, V_{ref} is issued on line 26a.

The drive torque M_{mot} may e.g. be the engine output torque (corresponding to the input torque of the mechanical transmission), or it may be the output torque of the mechanical transmission. When the influence of the mechanical transmission must be taken into account, the information about the gear step (line 23b) can be generated either by rotational speed analyses (engine rotational speed in comparison with wheel rotational speed) or by evaluation of an explicit signal (for example, in automatic transmissions).

Instead of the tabulated acceleration A_{tab}, an independently measured vehicle acceleration, e.g. from a sensor, A_{sens}, represented by line 16a, can also be taken into account for comparison in the comparator 25 in determined embodiments. Also, or instead thereof, a measured acceleration A_{sens} can be

used for the extrapolation of a vehicle reference speed V_{ref} for obtaining the modified vehicle reference speed V_{mod}.

The physical background will be illustrated briefly before an embodiment of table 24 is explained by making reference to Figure 3:

When all wheels spin (e.g. at a low coefficient of friction), all wheel sensors show wheel speeds which are considerably above the vehicle speed. Consequently, the vehicle reference speed V_{ref} determined from the wheel sensor signals is also supposed to be too high. The vehicle reference acceleration A_{ref} determined therefrom will also be too high. On the other hand, either the engine torque M_{mot} 23a, or the measured vehicle acceleration A_{sens} represents real conditions and especially lower accelerations. This is because when all wheels spin ('breakaway'), the drive torque (the torque output by the engine) will drop because 'only' the drive train has to be accelerated and the friction force between tire and roadway has to be overcome. The vehicle with its great mass no longer has to be accelerated. Therefore, plausible/possible vehicle accelerations may be deduced from the engine torque, if appropriate, in connection with the gear step and the vehicle speed, for example with the use of a table. The said accelerations may then be used for comparison with the vehicle acceleration A_{ref} which indirectly results from the wheel sensor signals.

Figure 3 shows an embodiment of table 24. It tabulates accelerations A_{tab} in dependence on engine torques M_{mot}. Values standardized with respect to the acceleration due to gravity g (= 9.81 m/s^2) are shown. The possible torque values M_{mot} are subdivided into ranges. Maximally possible vehicle accelerations are indicated for these ranges. The respectively

tabulated acceleration A_{tab} will rise with the rising engine torque M_{mot} as well. An exception in the tabulating operation is intended for very low drive torque values (especially for drag torques, negative drive torque, engine acts as brake). Again, higher acceleration values are indicated herein. This takes the possibility into account that a vehicle reference speed can prevail which is possibly too low. In the non-driven case (M_{mot} < 0), the vehicle reference speed can be led very quickly to the actual vehicle speed again by choosing the acceleration to be comparatively high (as shown) when the tabular value is then taken for extrapolation of the vehicle reference speed.

Besides, the gear step of the vehicle represents another input of the table of Figure 3. Equal drive torques M_{mot} cause different accelerations in different gear steps. Lower acceleration values A_{tab} are tabulated for higher gear steps. The possible engine torque range can be subdivided into three or more ranges (especially five or more ranges). Associated with each gear step can be one single table 'line'. Also, a distinction can be made within one gear step based on the vehicle speed.

However, to prevent an erroneous rise of the vehicle reference speed out of the overspeed phase during load shifts, i.e., during operation of the mechanical transmission, it is possible in the transition of the engine torque to values less than zero to modify the vehicle reference speed by extrapolation for a certain time still (e.g. 200 - 400 msec) with the least possible acceleration of the respective gear step (in Figure 3, second column from the right).

Figure 4 shows schematically a device for the detection of an incorrect vehicle speed of an all-wheel-drive vehicle. Identical or modified components like in Figure 2 can be used.

Reference numeral 40 designates a fourth determination system for determining the vehicle reference speed. It can e.g. comprise the reference numeral 20 of Figure 2 (components 21 to 26), or it can refer only to the first determination system 21. It can determine the vehicle reference speed with respect to the wheel signals from the sensors 11a-d and, if necessary, also in an extrapolated fashion, and output it via line 40a for further reference. Reference numeral 41 designates a part of a decoupling apparatus by which one or more wheels, e.g. the wheels of an axle, can be decoupled from the vehicle drive. The apparatus 41 may cooperate with e.g. a center clutch 14b in the vehicle by causing the center clutch 14b to open so that one of the axles, e.g. the rear axle, is decoupled from the drive. If these wheels are not braked, they may roll freely.

The wheels can be decoupled from the drive train based on driving conditions and, as the case may be, corresponding time variations in the vehicle which are examined or detected in a detection system 42. For this purpose, the detection system 42 receives most various signals 43 which may also comprise the wheel signals and further sensor signals as well as internal control signals. System 42 can also receive the vehicle reference speed 40a and/or the modified vehicle reference speed.

When defined conditions prevail, opening of the center clutch 14b is caused by means of apparatus (line) 41. The wheel signals of the decoupled wheels may then be monitored in their running behavior. This is done in the monitoring system 44 to which those wheel signals are applied which originate from the decoupled wheels. A quick decline of the respective wheel rotational speeds is an indication that traction slip prevailed so far. Thus, it may e.g. be checked whether the gradient (wheel acceleration) of one or more decoupled wheels after the

decoupling action is more negative than a negative threshold value.

The further course may e.g. be so that the signals of the still driven wheels are blanked out (represented by switch 45), and the vehicle reference speed is determined merely with reference to the wheel signals of the freely running wheels. Accordingly, a modified determination strategy would be employed in the determination system 40.

Decoupling the wheels of an all-wheel-drive vehicle from the drive train for detecting an incorrect vehicle reference speed may be suitable especially in the following situations:

1. The vehicle reference speed which is determined or extrapolated with reference to all wheel signals (e.g. on line 26a in Figure 2) is above the actual vehicle speed. The result is a traction slip control which is too insensitive. The vehicle is unstable or not steerable.

2. The vehicle reference speed is below the actual vehicle speed. The result is e.g. a too sensitive traction slip control because traction slip shows for the control which actually does not exist.

Ad 1.: The situation may occur at low coefficients of friction on the roadway (wet roadway, slick ice). All wheels spin and thus indicate a high vehicle speed which actually does not exist. When one axle is decoupled from the drive, the decoupled wheels are slowed down in a short time and adopt a rotational speed corresponding to the actual vehicle speed. This is represented as negative gradient of the wheel speed after the decoupling of the wheel from the drive. Then, the vehicle reference speed must be corrected to reach smaller values. To

detect this situation, several or all of the conditions mentioned in the following may be polled:

- Activation of the traction slip control; this criterion indicates that traction slip was detected.
- The vehicle reference speed is already no longer determined by making reference to the wheel signals, but is modified, e.g. extrapolated, as mentioned hereinabove. This criterion indicates that the wheel patterns exhibit unplausibly high values.
- The actual vehicle acceleration (for example, from the table according to Figure 3 or measured by a sensor) is lower than a low threshold value (e.g. < 0.2 g). This criterion furnishes a hint at a low coefficient of friction.
- The wheel slip is higher than a threshold (e.g. corresponding to 1.5 km/h). The driving action is detected by this criterion.
- The traction slip control of the engine uninterruptedly causes the increase of torque for a defined period of time (e.g. t > 1 sec), while a low coefficient of friction was detected simultaneously, or it is in the phase of torque reduction without interruptions (t > 2 sec).

Preferably, several or all above criteria are polled in an AND-fashion.

Ad 2.: The mentioned situation can appear when driving downhill at a low engine torque when the vehicle reference speed would be extrapolated with low acceleration values, for example, from table 3. When driving downhill, the engine torque does not determine the vehicle acceleration, and a longitudinal acceleration sensor does not represent the actual vehicle acceleration. Thus, the determined vehicle reference speed can

stay behind the actual vehicle speed. When such a situation prevails, the isolation of wheels from the vehicle drive will cause an only insignificant modification of the wheels' rotational speed because the wheels did not exhibit any traction slip. In this case, the vehicle reference speed will be corrected towards higher values in order to adapt to the actual vehicle speed. To detect this possible situation, i.e., to trigger decoupling of wheels from the drive, several or all of the following conditions can be checked, and these should be fulfilled preferably for a minimum duration (e.g. 300 msec, or more):

- When a longitudinal acceleration sensor is provided, the acceleration signal of the sensor is by one threshold lower than the vehicle reference acceleration determined from the wheel signals. This is an indication of a hill ascent/descent.
- The engine torque must exceed zero. This gives a hint to the driving action, the engine does not act as an engine brake.
- The wheel accelerations and/or the wheel speeds of all wheels must exhibit a stable wheel behavior (wheel accelerations are lower than a threshold value). This will prevent traction slip situations ('breakaway') of wheels.
- The wheel speeds of the wheels must be above the vehicle reference speed.

Preferably, the isolation lasts no longer than 2000 msec. The duration of the isolation of the wheel(s) from the drive train can amount from 300 to 1000 msec.

When an incorrect vehicle reference speed was detected in the above situations 1. or 2., a modified determination strategy can be employed. For example, the vehicle reference speed can

then be determined with reference to the running behavior and, in particular, with reference to the wheel speeds of the decoupled wheels because the said wheels, unless braking takes place, will adopt (case 1.) or have already adopted (case 2.) a rotating speed corresponding to the actual vehicle speed at a comparatively fast rate.

Figure 5 shows schematically a method of determining the vehicle reference speed which combines the above-described strategies. Defined conditions (cond. 1) are checked after the commencement of the method in step 51. As long as these conditions are satisfied, the vehicle reference speed V_{ref} is determined in step 52 from the wheel speeds $\omega1$ to $\omega4$ of all four wheels of the vehicle. When these conditions are not satisfied, further conditions are checked in step 53. When these conditions are satisfied, the vehicle reference speed is no longer determined at least exclusively with reference to the wheel speeds in step 54. For example, the vehicle reference speed can be extrapolated on the basis of values which were as last plausible. When the conditions are not either satisfied in step 53, individual wheels, i.e., the wheels of one axle, can be decoupled from the vehicle drive in step 55, and the vehicle reference speed can then be determined with reference to the wheel signals of the decoupled wheels.

The poll in step 51 can be executed, for example, by the components 23 to 25 in Figure 2. The vehicle reference speed would be determined in the system 21 according to step 52, and the determination according to step 54 would be performed by activation of the modification system 26 in Figure 2. The conditions in step 53 can be implemented in the system 42 in Figure 4.

The running behavior of the decoupled wheels can be checked after the decoupling action in step 56. In the presence of defined criteria, either the extrapolated value is continuously used (step 54), or V_{ref} is determined in the future with reference to the wheel speeds of the decoupled wheels.

The polling operation in step 56 can be implemented in the system 44 which can execute different polls on the wheel signals in dependence on the detection of the driving situation in the detection system 42. The determination according to step 57 would correspond to the modified reference speed determination in the fourth determination system 40 with reference to only two wheel signals.

The steps shown in Figure 5 can also represent components of a device for implementing the method described hereinabove.

The implementation of the method mentioned hereinabove can be effected in a suitably programmed computerized control.